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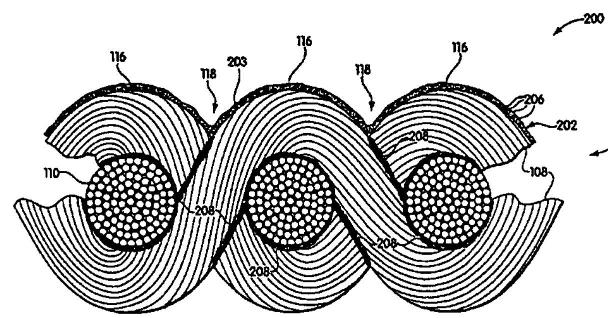
(54) Title: COATED PROTECTIVE FABRICS



(57) Abstract: The current invention discloses coated protective fabrics and methods for coating fabrics that can improve the puncture resistance, abrasion resistance, cut resistance, and/or durability of the fabric, while maintaining a relatively soft hand feel of the fabric and/or maintaining the drapability or breathability of the fabric to allow for mobility and comfort of a wearer. The disclosed coatings and coating methods can be applied to a wide variety of fabrics to improve their performance including high-cover, tightly woven fabrics and fabrics formed of high-strength performance fibers, for example, those having a tensile breaking strength exceeding about 10-15 g/denier. Some of the described coatings are formed of polymer materials having a relatively low level of hardness, for example having a modulus of elasticity less than about 100,000 psi. Some of the disclosed coatings also include dispersed therein one or more abrasive particulate materials to improve the level of cut/puncture resistance of the coating. A variety of coating configurations are described, including coating layers applied to a surface of a fabric so as to form a conformal coating layer that essentially continuously covers at least a portion of the fabric surface and substantially conforms to the topology of the fabric surface. The coated protective fabrics provided by the invention may be utilized to form a wide variety of garments and products useful as rugged outerwear/sportswear, industrial safety/protective equipment/garments, protective equipment/garments designed for law enforcement/military use, etc.

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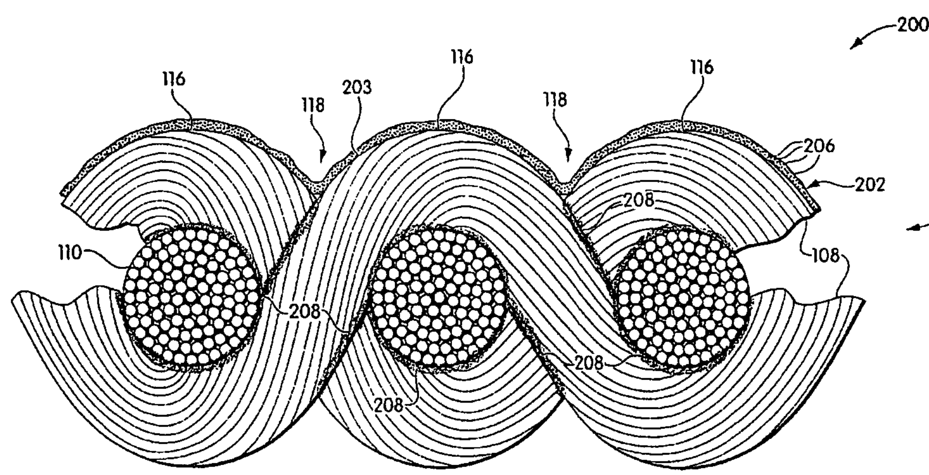

(57) Abstract: Coated protective fabrics and methods for coating fabrics to improve puncture resistance, abrasion resistance, cut resistance, and/or durability of the fabric, while maintaining a relatively soft hand feel and/or the drapability or breathability are disclosed. The fabrics can be high-cover, tightly woven fabrics and fabrics formed of high-strength performance fibers, for example, those having a tensile breaking strength exceeding 10-15 g/denier. The coating can be of polymer materials having a relatively low level of hardness and can contain dispersed therein one or more abrasive particulate materials. This coating layer can continuously cover the fabric surface and conform to the topology of this fabric surface. These coated protective fabrics may be used in garments and products useful as rugged outerwear/sportswear, industrial safety/protective equipment/garments, etc.

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COATED PROTECTIVE FABRICS

Related Applications

This application claims priority from co-pending provisional specification 60/160,290 filed October 18, 1999, incorporated herein by reference.

Field of the Invention

The invention relates to coated fabrics and methods for coating fabrics for improving their resistance to puncture and/or their resistance to cut and/or abrasion while substantially maintaining the hand and drapability of the fabrics.

Background of the Invention

Protective fabrics having high puncture, abrasion, and cut resistance have a wide range of industrial applications for the construction of protective armor and protective clothing for use in protecting against a wide variety of assaults. Such protective clothing and armor often is utilized by police and prison guards, among others, and is designed to be capable of withstanding assault by a variety of instruments, such as bullets, knives, etc.

Typical prior art protective vestaments are often constructed of fabrics including various high performance fibers having high tensile breaking strengths, for example Kevlar®. Many such prior art vestaments can be useful for preventing penetration of relatively large penetrators, for example those having a maximum cross sectional size greatly exceeding the diameter of the yarns comprising the fabrics in the protective vestaments, but are typically less effective at preventing penetration by small sharp penetrators, for example needles, ice picks, snake fangs, thorns, etc., having relatively small cross sectional diameters, for example, less than 0.1 inches. Moreover, typical prior art protective vestaments often are constructed from a large number of layers of protective fabric, and may also be laminated with layers of other penetration-resistant materials, for example ceramics disks, etc., in order to improve penetration resistance. Such constructions typically result in articles which are relatively stiff and not readily drapable. Accordingly, such articles are not ideally suited for use as articles of clothing where comfort and mobility of a wearer are important.

Uses of protective fabrics where comfort and mobility of a wearer are important, and where typical prior art protective articles are not ideally suited, include the use of protective

fabrics for constructing gloves, and in the manufacture of rugged outerwear, for example, for use in hunting, hiking, fishing, extreme sports, and other outdoor activities. Protective fabrics can also be useful in a number of safety related applications and be used in garments such as aprons, gauntlets, and boots. For such applications, providing cut, puncture, and abrasion resistance while at the same time maintaining a soft hand feel and drapability of the protective fabric can be critical for customer satisfaction and acceptance.

Coating protective protective fabrics to improve their resistance to penetration by sharp penetrators is described in U.S. Patents 5,565,264 and 5,837,623, both to Howland. The '264 and '623 patents to Howland describe methods for weaving high cover fabrics from multifilament yarns comprised of performance fibers, and further describe coating these fabrics with a high-modulus epoxy resin to improve their penetration resistance. However, because the high-modulus epoxy resin used substantially stiffens and severely impairs the drapability of the base fabric, the resin is applied to the fabric in a discontinuous pattern leaving regions of the fabric uncoated in order to provide flexation points so that the fabric can be rendered bendable and drapable.

While the above described protective fabrics and articles produced therefrom can provide improved resistance to penetration, cutting, and abrasion, there remains a need in the art for relatively light-weight protective fabrics that are able to resist penetration by small diameter, sharp penetrators, while also having a sufficient degree of drapability and soft hand for use in applications such as protective gloves, and other articles of protective clothing where mobility of a wearer is at a premium, for example rugged outerwear, safety equipment, and sporting apparel.

Summary of the Invention

The current invention, in some embodiments, provides coated protective fabrics and methods for coating fabrics that can improve at least one of the puncture resistance, abrasion resistance, and durability of the fabric, while maintaining a relatively soft hand feel of the fabric and/or maintaining the drapability of the fabric to allow for mobility and comfort of a wearer.

In one aspect, a series of articles are disclosed. The article in one embodiment comprises at least one layer of fabric and at least one coating layer including a polymeric material that is disposed on at least a portion of at least one surface of the fabric. The

polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 500,000 psi and preferably not exceeding about 100,000 psi. The coating layer further includes dispersed therein at least one abrasive particulate filler material. The coating layer is disposed on the surface of the fabric such that at least a portion of the surface is conformally coated with the coating layer.

In another embodiment, an article is disclosed that comprises at least one layer of a fabric, where the fabric includes at least one performance fiber having a tensile breaking strength of at least 10 grams/denier (g/denier). The coated fabric further comprises at least one coating layer including a polymeric material that is disposed on at least a portion of at least one surface of the fabric. The polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 500,000 psi and preferably not exceeding about 100,000 psi.

In another embodiment, an article is disclosed that comprises at least one layer of a woven fabric and at least one coating layer including a polymeric material that is disposed on at least a portion of at least one surface of the fabric. The coating layer further includes dispersed therein at least one abrasive particulate filler material. The coating layer is disposed on the surface of the fabric such that at least a portion of the surface is conformally coated with the coating layer.

In yet another embodiment, an article is disclosed that comprises at least one layer of a woven fabric and at least one coating layer including a polymeric material that is disposed on at least a portion of at least one surface of the fabric. The polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 500,000 psi and preferably not exceeding about 100,000 psi. The coating layer further includes dispersed therein at least one abrasive particulate filler material.

In another embodiment, an article is disclosed that comprises at least one layer of fabric including therein at least one performance fiber having a tensile breaking strength of at least about 10 g/denier. The article further comprises at least one coating layer disposed on at least a portion of at least one surface of the fabric and comprising a barrier material that is permeable to a gas but essentially impermeable to liquid water.

In another aspect, a method is disclosed. The method involves dispersing at least one abrasive particulate filler in a liquid that is able to form a solid film on a surface, where the film includes a polymeric material. The polymeric material has a modulus of elasticity not

exceeding about 500,000 psi and preferably not exceeding about 100,000 psi. The method further comprises applying the liquid onto a surface of the fabric, spreading the liquid across at least a portion of the fabric surface to form a liquid layer on the fabric surface that substantially conforms to a surface topology of the fabric, and allowing the liquid layer to solidify to form a conformal coating layer upon the fabric surface.

In another embodiment, a method is disclosed. The method involves supplying a liquid that is able to form a solid film on a surface, where the film includes a polymeric material that has a modulus of elasticity not exceeding about 500,000 psi and preferably not exceeding about 100,000 psi. The method further comprises applying the liquid onto the surface of a fabric that includes at least one performance fiber having a tensile breaking strength of at least about 10 g/denier. The method further comprises spreading the liquid across at least a portion of the fabric surface to form a liquid layer on the fabric surface and allowing the liquid layer to solidify to form a coating layer on the fabric surface.

In yet another embodiment, a method is disclosed. The method comprises applying a film-forming liquid to a fabric surface and spreading the liquid across at least a portion of the surface by utilizing a spreading blade formed of a flexible elastomeric material, where, during the spreading step, the blade is maintained in essentially direct contact with the liquid on the fabric surface.

In another embodiment, a method is disclosed. The method comprises combining at least one layer of fabric including therein at least one performance fiber having a tensile breaking strength of at least about 10 g/denier with at least one coating layer comprising a barrier material that is permeable to a gas but essentially impermeable to liquid water, so that the coating layer is disposed on at least a portion of at least one surface of the fabric.

Other advantages, novel features, and objects of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings, which are schematic and which are not intended to be drawn to scale. In the figures, each identical or nearly identical component that is illustrated in various figures is represented by a single numeral. For purposes of clarity, not every component is labeled in every figure.

Brief Description of the Drawings

FIG. 1 is a schematic illustration of a cross section of fabric showing an end-on view of three fill yarns and further showing a non-conformal laminated coating layer;

FIG. 2 is a schematic illustration of a cross section of fabric showing an end-on view of three fill yarns and further showing a non-conformal coating layer essentially completely filling the interstices between the warp yarns;

FIG. 3 is a schematic illustration of a cross section of fabric showing an end-on view of three fill yarns and further showing a conformal coating layer according to the invention of a polymeric material having an abrasive particulate filler disposed therein;

FIG. 4 is a flow chart illustrating steps of a fabric coating method according to some embodiments of the invention; and

FIG. 5 is a schematic illustration of a knife over air process for forming a conformal coating on a fabric, according to one embodiment of the invention.

Detailed Description

In accordance with one embodiment of the present invention, a protective fabric providing penetration and/or abrasion resistance is formed by coating a layer of a woven or non-woven fabric with at least one coating layer that includes a polymeric material. The coating layers according to the invention are, in some embodiments, disposed on only one surface of the fabric; however, in alternative embodiments where stiffness and drapability of the fabric is less important, both sides of the fabrics may be coated with a coating layer. As described in more detail below, the polymeric coating materials and the methods for coating the fabrics can allow for enhancing at least one of the penetration, cut, and/or abrasion resistance of the fabrics (hereinafter also collectively referred to simply as "penetration resistance") , while, preferably, at the same time maintaining a relatively soft hand feel and drapability of the fabric.

The coated fabrics provided according to certain embodiments of the invention can also, in some instances, provide improved dyability, printability, washability, and weather resistance to a base fabric upon which the coating is disposed. In some preferred embodiments, the coating can be further selected so that the coated fabric also substantially retains its gas permeation characteristics and thus remains breathable to provide comfort for a wearer. The inventive fabrics described herein have a wide variety of applications. One particular use for the inventive fabrics is in the manufacture of protective vestaments and

apparel, for example, in the manufacture of protective gloves and other articles of protective industrial or other clothing, such as aprons, chaps, gauntlets, gators, boots, etc., as well as in the manufacture of rugged outerwear for use as hunting apparel or apparel for other sporting applications. The coated protective fabrics described herein can be used, especially where maximum flexibility and comfort is desired, as a single layer in the manufacture of apparel, or, alternatively, may be configured as multiple layers or laminated with other fabric layers or materials to provide additional protection or other desirable properties.

As described in more detail below, the inventive coated fabrics preferably include coating layers that include a polymeric material comprising one or more low modulus, relatively soft elastomeric materials. Utilization of such low modulus polymeric coating materials, unlike the high modulus epoxy resin materials typically used in prior art coatings for protective fabrics, can enable the surface of the fabric to be coated with an essentially continuous layer of the low modulus polymeric material, while substantially maintaining flexibility of the fabric and not unduly increasing its stiffness or reducing its hand and drapability.

A wide variety of low modulus polymeric materials are potentially useful for forming the fabric coatings according to the invention. Such polymeric materials can be natural or synthetic polymers and preferably comprise elastomeric materials having a modulus of elasticity not exceeding about 500,000 psi, more preferably not exceeding about 100,000 psi, more preferably not exceeding about 50,000 psi, more preferably not exceeding about 10,000 psi, and more preferably not exceeding 5,000 psi. "Modulus of elasticity" as used herein in reference to the hardness of polymeric materials used for forming coating layers on fabrics refers to the modulus of elasticity of the polymeric material when in a substantially pure solid form, excluding other additives introduced into the material during the coating processes described in more detail below.

Polymeric materials used for forming coating layers according to the invention should be capable of forming relatively thin, essentially continuous films. In some embodiments, a coating layer may be applied to a surface of a fabric as a pre-formed solid film, for example, by lamination of the film to the surface of the fabric. However, in more preferred embodiments, the coating layer is formed on the surface of the fabric by depositing a liquid that is able to form a solid film including a polymeric material on the fabric surface, spreading the film onto the surface of the fabric, and allowing the spread liquid layer to

solidify to form the polymeric coating layer. A "liquid that is able to form a solid film including a polymeric material" as used herein refers to any liquid that can be applied to and spread onto the surface of a fabric, which can subsequently be solidified to form a polymeric coating layer on the fabric surface. Such liquids can comprise, for example, polymeric materials at a temperature above their glass transition temperature (i.e., hot melt polymers), polymeric emulsions, solutions, suspensions, mixtures of monomers or pre-polymers, or combinations of the above, or other liquids that are able to solidify upon a surface to form a coating layer. Such solidification may occur, for examples, by cooling below a glass transition temperature, polymerization, crosslinking, evaporation of a solvent, etc., or combinations thereof. A wide variety of known polymeric materials can potentially be utilized for forming the inventive fabric coatings and can include, for example, various rubber compositions, such as curable rubbers and silicone rubbers, poly vinyl chloride compositions, polyurethanes, such as poly ether urethane, acrylic latex polymers, and other low-modulus polymers known in the polymer arts. Hetrofore, such soft resin, low-modulus coating materials were not typically employed in the protective fabric arts.

Some preferred coatings according to the invention utilize polyurethanes or acrylic latex polymers, and in some especially preferred embodiments, the coatings are formed of an acrylic latex polymer. Formulations of the above mentioned polymers capable of forming coatings are known in the polymer and coating arts and many are commercially available. Polymers, such as the above-mentioned polyurethanes and acrylic latex polymers, that are able to form a coating of a barrier material that is permeable to gases, such as air and water vapor, but essentially impermeable to liquids, such as water, are especially preferred. Such barrier material coatings enable the coated fabrics to be rendered water resistant or essentially "water proof," while allowing good breathability via the permeation of air through the material and/or the escape of water vapor from a wearer via evaporation from the body and permeation through the coated layer of barrier material.

In some preferred embodiments, as discussed in more detail below, acrylic latex emulsions are utilized for forming the inventive polymeric fabric coatings. Such acrylic latex emulsions are available, for example, from BF Goodrich® Specialty Chemicals (Lawrence, MA) in a variety of formulations, for example Sancure® 861, Hycar® 2679, and Sancure® 13077, and others. Coatings formed from the above mentioned acrylic latex emulsions have

been found to enable substantial maintenance of the hand and drapability of the fabric while providing increased yarn stability within the fabric, good breathability, high wash resistance and resistance to hydrolysis, and improved dyability and printability of the coated fabric. The improvement in the colorability of the inventive coated fabrics, for examples, by dying, printing, and/or addition of colored pigments to the coatings can provide an important commercial advantage to the inventive protective fabrics when compared to typical prior art fabrics. This advantage is especially important for embodiments involving fabrics comprised of performance fibers such as, for example, para-aramids such as Kevlar®, which are not easily colorable by typical prior art techniques.

As discussed in more detail below, in certain preferred embodiments, various additives may be dispersed into the liquid used for forming a coating layer on the fabric (e.g., an acrylic latex emulsion) for various purposes including improving the film-forming characteristics of the liquid, increasing the puncture and/or abrasion resistance of the coating, coloring the coating, etc. For example, in some particularly preferred embodiments, a quantity of a granular abrasive particulate filler material is dispersed in the liquid used for coating the fabric. Such abrasive particulate filler materials are useful for increasing at least one of the puncture, cut, and abrasion resistance of the coated fabric, by, in part, providing a high level of frictional resistance to an object penetrating the fabric. The particular fillers preferred for use in the current invention as well as their preferred characteristics are discussed in greater detail below in the context of the preferred methods for coating fabrics according to the invention.

The inventive fabric coatings and coating methods described herein can be utilized to improve the protective properties of a wide variety of woven and non-woven fabrics formed of a wide variety of natural and/or synthetic fibers, such as, for example, polyester, nylon, polypropylene, and cotton fibers. For example, practically any woven fabric can potentially be utilized as the base fabric used for forming coated protective fabrics according to the invention. In some preferred embodiments, the base fabrics utilized include at least one performance fiber as part of the fabric structure. A "performance fiber" as used herein refers to a fiber that has a tensile breaking strength of at least 10 g/denier, and more typically at least 15 g/denier. Such high performance fibers, when utilized for forming woven fabrics, inherently impart some degree of penetration and cut resistance to the resulting fabric. In some preferred embodiments, the woven fabric is essentially completely comprised of yarns

that are formed form a plurality of such performance fibers. Some performance fibers are well known in the protective fabric arts and include fibers formed of para-aramids (e.g., Kevlar®, Twaron®, and Technora®), liquid crystal polyesters (e.g., Vectran®), ultra-high molecular weight polyethylenes (e.g., Spectra®), and poly(p-phenylene-2,6-benzobisoxazole) (PBO) (e.g. Zylon®).

In some preferred embodiments, the base fabrics comprise a high yarn density, high cover, tightly-woven fabric. In some such preferred embodiments, such high cover fabrics comprise the Kevlar® fabrics described in commonly owned U.S. Patents 5,565,264 and 5,837,623 both incorporated herein by reference in their entireties. The reader is referred to the above mentioned patents for greater detail concerning the performance base fabrics briefly described immediately below. As described in the above referred to patents, such densely woven fabrics inherently can provide a high degree of protection and inherently can have a high degree of resistance to puncture. Such fabrics, as described in the above referred to patents, typically have a warp yarn density ranging from at least about 90 warp yarns/inch of fabric to at least about 130 warp yarns/inch of fabric, and have a fill yarn density of at least about 65 fill yarns/inch of fabric to about 90 fill yarns/inch of fabric. The fabrics above typically are constructed either as 200 x 200 denier or 200 x 400 denier (warp yarn denier x fill yarn denier). The yarns in the above mentioned fabrics can be formed from continuous filament fibers or from twisted shorter length staple fibers. The above mentioned fabrics can provide a warp yarn cover factor of at least 100% and up to about 140%, at the center of the fill yarn, for some embodiments, and can provide a fill yarn cover factor of at lest about 75%, as measured between two warp ends. One preferred woven fabric, described in the above-mentioned patents, for use in the current invention, is formed of warp yarns and fill yarns formed of 100% Kevlar® 1.5 inch staple filaments spun into Kevlar® yarns. This preferred fabric has a construction utilizing 200 denier multifilament warp yarns (50/2 cotton count) and 400 denier multifilament fill yarns (25/2 cotton count) at a weaving density of about 110 warp yarns/inch by about 67 fill yarns/inch. This fabric provides a warp yarn cover factor of between about 130 and 140% and a fill yarn cover factor of about 85%. As described in the '264 and '623 patents referred to above and as apparent to those of ordinary skill in the art, warp yarn "cover factor" refers to a measure of the amount of overlap between adjacent warp yarns as measured at the fill crossing and can be determined as the sum of each of the widths

of the warp yarns in a given cross section divided by the total length of the cross section. When calculating the fill yarn "cover factor," because there is a warp yarn positioned between each of the fill yarns due to the crimp in the woven structure, the proper "effective yarn width" of the fill yarns utilized in the calculation is equal to the sum of the widths of a fill yarn and a warp yarn, as measured between the fill crossings

As discussed in more detail below, the coated fabrics provided according to the invention preferably include a coating layer that is disposed on a surface of the fabric such that at least a portion of the surface is conformally coated with the coating layer. A "conformal" coating layer or a surface that is "conformally coated" with a coating layer, as used herein, refers to a coating layer that is disposed on a surface of a fabric such that the layer is essentially continuous and uninterrupted on a least a portion of the surface and has a shape which substantially conforms to the surface topology and contour of the fabric surface, while not completely penetrating or soaking through the cross sectional thickness of the fabric. The meaning of a "conformal coating" as used herein is best illustrated with reference to FIGs. 1-3 which show examples of non-conformal coatings (FIGs. 1 and 2) and conformal coatings (FIG. 3) as provided according to the invention.

FIG. 1 shows a coated fabric 100 having a non-conformal coating layer 102 disposed on an upper surface of fabric 104. Fabric 104 is comprised of a plurality of multifilament yarns including warp yarns 108 and fill yarns 110. The structure of the yarns is more clearly seen by considering fill yarns 110 shown in cross section. Fill yarns 110 are formed of a plurality of individual filaments or fibers 112. As described above, in preferred embodiments, the yarns are preferably formed of fibers (such as 112) which are high performance fibers, for example, Kevlar® fibers.

Non-conformal coating layer 102 does not conform to the topological shape of fabric surface 114, but instead simply rests upon the surface and is in contact with fabric 104 only at the high points 116 of warp yarns 108. Specifically, coating layer 102 does not conform with and is not in contact with fabric 104 in valley regions 118. Coating layer 102 is typical of a layer deposited by layering, lamination, or bonding of a pre-formed polymeric film to a fabric surface. Coatings such as 102 are less preferred than conformal coatings in the context of the present invention because they are not as effective at stabilizing the movement of the yarns comprising the base fabric upon exposure to a penetration or cutting threat.

FIG. 2 shows another coated fabric 150 that includes a non-conformal coating layer 152, which permeates and fills essentially all the interstices throughout the cross section of fabric 154. Coating 152 is typical of coatings that are formed by applying, and essentially completely saturating, a fabric with a liquid coating solution that subsequently solidifies to form a coating such as 152. When applied by conventional coating techniques, for example utilizing a knife over air or knife over roll coating machine, coating layer 152 is typically scraped off the fabric at high points 116 of warp yarn 108 so that the coating is non-continuous on the fabric surface. Furthermore, coating layer 152 does not have a shape that conforms to the surface topology of fabric 154. Instead, coating 152 is discontinuous at the high points 116 of fabric 154 and completely fills up valleys 118 defined by warp yarns 108. Such a coating is typically less desirable than the conformal coatings described below for coated fabrics provided according to the invention for at least two reasons. First, while, in some cases providing enhanced stability and resistance to movement of the yarns of fabric 154, coating 152 leaves a considerable surface area of the coated fabric (i.e., the areas defined by high points 116) which are largely unprotected and do not fully benefit from the protective properties of the coating layer. In addition, because coating layer 152 essentially completely fills the interstices within the cross section of fabric 154, the coating will have a tendency to substantially stiffen the fabric thereby reducing its drapability and hand to an undesirable extent.

FIG. 3 illustrates a coated fabric 200 produced according to a preferred embodiment of the invention. Coated fabric 200 includes a conformal coating layer 202 disposed, in the illustrated embodiment, on one surface 203 of fabric 204. As shown, conformal coating 202 is essentially continuous across the surface of fabric 204, even at high points 116 of warp yarns 108. Furthermore, conformal coating layer 202 has a shape and contour which substantially conforms to the surface topology of fabric 204. Conformal coating layer 202 preferably conforms to and adheres to the surface of warp yarns 108 within valley regions 118, but, unlike coating 152 shown in FIG. 2 above, conformal coating layer 202 preferably does not completely fill up the void space defined by valleys 118. In especially preferred embodiments, conformal coating 202 is applied to fabric 204 so that it has a substantial uniform thickness across the fabric surface that is coated. Conformal coating 202 also, as shown in FIG. 3, preferably does not penetrate through or saturate the entire cross section of fabric 204. Accordingly, conformal coating layer 202 is able to provide an essentially

continuous and uninterrupted layer of protection to the fabric surface, which can improve the puncture, cut, and abrasion resistance of the base fabric, in part, by densifying and immobilizing the fibers and yarns at the crossing points in the weave of the fabric. In addition, because conformal coating layer 202 does not completely fill the interstices of the cross sectional thickness of fabric 204, it has a reduced tendency to increase the stiffness of fabric 204, and can allow coated fabric 200 to retain a substantial degree of the drapability and hand of the base, uncoated fabric.

As described in more detail below, in preferred embodiments, conformal coating layer 202 can be formed by applying a layer of a liquid coating solution, suspension, emulsion, molten polymer, etc., which is able to form a solid polymeric film, onto the fabric surface and spreading the liquid onto the surface using a novel spreading technique, described in more detail below. However, in alternative embodiments, it is also contemplated that coating layer 202 could be formed by applying a preformed solid polymeric film to the fabric surface, conforming the film to the topology of the fabric surface (for example by using an applied pressure or vacuum) and a bonding/laminating the film to the fabric surface.

Coating layer 202 of coated fabric 200 also preferably includes a plurality of grains of abrasive particulate filler material dispersed within the coating layer. In addition to the abrasive particulate filler materials, coating layer 202 may also include other additives, for example dyes or color pigments to impart a color to the coated surface of coated fabric 200. As discussed previously, abrasive particulate filler materials can improve the abrasion resistance and puncture resistance of coated fabric 200 and can also, in certain embodiments, enhance the film-forming properties of a liquid coating solution used for forming coating layer 202. For example, for embodiments where coating layer 202 is formed utilizing acrylic latex emulsions, the inventors have found that the addition of particulate carbon black to the acrylic emulsion not only can improve the abrasion and puncture resistance of the resulting acrylic polymer film, but also tends to improve the coating properties of the acrylic latex and also provides pigmentation (i.e., a black color) to coated fabric 200. In addition to, or in place of carbon black particulate fillers, certain preferred embodiments of coating layer 202 also include dispersed therein a plurality of grains of one or more inorganic high-hardness, high-friction materials. Such materials are especially beneficial for applications where a high degree of abrasion and/or puncture resistance is desired, since such materials, owing to their hardness and typically jagged and rough shape, can greatly increase the frictional resistance

to passage of a penetrator, such as a needle or thorn, through the coated fabric. A wide variety of particulate fillers can be utilized according to the invention. Such materials are known in the abrasives and grinding arts and include, for example, ceramic materials such as silicon carbide, aluminum oxide, silicon dioxide, sapphire, garnet, etc. In addition, industrial diamond abrasives may also be used as abrasive particulate filler material according to the invention. While a wide range of particle sizes for the abrasive particulate filler material can be used depending on the needs of a particular application, preferred carbon black average particle sizes range from about 13 nm to about 75 nm, with average particle sizes within the range of about 25 nm to about 50 nm being especially preferred. Preferred particle sizes for the inorganic high-hardness, high-friction materials/industrial diamond materials fall within the range of mesh sizes (roughly equivalent to the number of particles that can be aligned end to end per linear inch) of between about 80 mesh and about 6400 mesh, with mesh sizes of between about 200 to 300 being especially preferred.

Coated fabric 200, illustrated in FIG. 3, also includes a layer of polymeric material 208 bonded to the surfaces of warp yarns 108 and fill yarns 110, which serves to stabilize the yarns of fabric 204 to increase their resistance to a penetrating, abrading, or cutting force. As described in more detail below in the context of a preferred method for forming coated fabric 200, interstitial coating 208 can be formed by allowing a polymer-containing or polymer-forming liquid to wick into and substantially penetrate a cross section of fabric 204, without completely saturating the interstices of fabric 204, and subsequently allowing the liquid to solidify thereby depositing a polymer within the structure of fabric 204. Such a technique is referred to herein as a "semi-saturation coating," and such coatings can enhance the penetration resistance of the coated fabric without unduly compromising the hand and drapability of the fabric, as contrasted with coatings which completely saturate the fabric, such as those shown previously in FIG. 2.

Described in detail below is one preferred method for forming the inventive coated protective fabrics as described above, and shown, for example, in FIG. 3. While it should be emphasized that a wide variety of polymeric coating materials may be utilized according to the invention, including a wide variety of materials that enable the formation of a polymeric coating layer by applying a liquid that is able to form a solid polymeric film to a surface, in the description below, an exemplary embodiment utilizing coatings formed from water-based acrylic latex emulsions is described in order to outline and highlight important features and

steps of coating methods useful for forming coated fabrics according to the invention. It should be understood that the various concentrations, additives, coating densities, etc., described below are purely exemplary and that the use of other coating systems and/or materials may require adjustment of the methods described herein combined with routine experimentation and optimization in order to achieve desired coated fabric properties, as would be apparent and well within the skill level of those of ordinary skill in the art.

In addition, the particular choice of materials and conditions for forming the inventive coated fabrics will depend, in large degree, on the desired final properties of the coated fabric being produced. Specifically, conditions and materials which tend to increase puncture resistance also, in many instances, also tend to increase the stiffness of the coated fabric. Therefore, the conditions and materials selected will depend upon a particular degree of puncture resistance, drapability, and hand required or desired of a coated fabric for a particular application. Accordingly, it is not possible to generalize or provide comprehensive listing of conditions and materials to form the entire range of coated fabrics falling within the scope of the present invention. However, those of ordinary skill in the art will be able to readily modify, if necessary, the teachings and methods described herein utilizing the level of skill possessed by those of ordinary skill in the art together with routine experimentation and well known testing methods to produce coated fabrics having desirable properties for any particular application.

In general, the use of higher modulus, harder polymeric coating materials, increasing coating density (i.e., weight of coating material applied per unit area of the fabric surface), and increasing the concentration of particulate abrasives within the coating will all tend to increase the puncture resistance of the coated fabric, but also will tend to increase the stiffness and reduce the hand and drapability of the fabric. Ultimately, optimal conditions for producing a particular desired set of properties for a coated fabric are selected via routine experimentation and optimization involving, for example, the above mentioned parameters. Fabrics produced according to various conditions can be subjected to a variety of screening tests to determine their properties and assist in determining appropriate coating conditions for a particular application. Such screening tests include the general hand and feel of the fabric, microscopic analysis (e.g., transmission electron microscopy and/or scanning electron microscopy) of the coated fabrics to observe the topology of the coating layers, and a variety of ASTM tests for determining the circular bending resistance and needle penetration

resistance of the fabric, and cut and abrasion resistance of the fabric for example ASTM D4032 and ASTM F1342, ASTM S1790, and ASTM D3884 tests respectively.

The flow diagram of FIG. 4 illustrates the basic steps for forming certain embodiments of coated protective fabrics according to the invention. As discussed above, the method according to FIG. 4 will be described via an illustrative embodiment. The embodiment illustrated involves forming at least one conformal coating layer by using an acrylic latex emulsion on a woven base fabric. The conditions described below were selected to yield a coated fabric having a puncture resistance increased, as compared to the uncoated base fabric, by up to about a factor of two, for a single layer of fabric, as measured by a needle penetration test, while having a stiffness, as measured by ASTM D4032 circular bending test for a single layer of coated fabric, increased over the base fabric by less than about a factor of two.

The overall method comprises an optional semi-saturation coating step (step 1) for forming a thin, stabilizing polymeric coating layer within the structure of the fabric (for example, see coating layer 208 in FIG. 3 above). This is followed (in step 2) by the formation of one or more conformal coating layers on a surface(s) of the fabric (for example coating layer 202 shown above in FIG. 3) which, in some embodiments, may be followed with an optional step 3 for forming an abrasive-free top coating on the coated fabric.

Each of the coating steps above can be performed utilizing standard fabric coating equipment known in the art, for example a knife over roll or knife over air coating machine. Such a coating machine is shown in rough schematic form in FIG. 5. FIG. 5 illustrates a knife over air coating machine 300 wherein fabric 302 is fed under tension over tensioning rollers 304 and 306 in the direction of arrow 308. Displaced above fabric 302 is a dispenser 310 configured to dispense a coating liquid (e.g., for the illustrated embodiment an acrylic latex emulsion-based coating liquid) at a controllable rate onto the fabric surface. Directly downstream of applicator 310 is a spreading element 312 including a blade 314 in contact with the surface of fabric 302, which serves to essentially uniformly distribute coating liquid 316 onto the fabric surface to form a coated surface 318.

In optional step 1, a semi-saturation coating is applied to the base fabric. The acrylic latex emulsions utilized for the various coating methods outlined in FIG. 4 are typically supplied from the manufacturer in a water base containing about 30 to about 40% acrylic latex solids. Such emulsion is hereinafter referred to as a "base emulsion" or "base solution".

As described below, various additives and modifiers may be added to the base emulsion in varying amounts to form what is hereinafter referred to as the "coating liquid". The coating liquid utilized for the semi-saturation coating step, in some preferred embodiments, may include a low concentration of carbon black (e.g., less than or equal to about 10% wt. of the coating liquid and preferably less than about 5% wt.), but, preferably does not include other abrasive particulate fillers. As discussed above, it is preferable that the coating liquid used for the semi-saturation coating step be applied to the fabric surface so that it is able to wick into the fabric structure by capillary action without completely saturating the interstices of the fabric structure. This can be accomplished by adjusting the viscosity of the coating to have a slurry-like consistency so that the liquid is able to wick into the base fabric without rapidly saturating it. If necessary, the viscosity of the coating liquid can be adjusted via adding an appropriate viscosity modifying agent to the emulsion. A wide variety of viscosity modifying agents can be used for this purpose, as apparent to those of ordinary skill in the art, for example fumed silica. The optimal viscosity of the semi-saturation coating liquid will, of course, depend upon the particular properties of the base emulsion, added fillers, and base fabric and must be determined for each application via routine experimentation and optimization.

Referring to FIG. 5, the inventors have found that, typically, an appropriate viscosity for the semi-saturation coating liquid is such that when applied to fabric 302, the coating liquid has a viscosity such that it does not immediately penetrate into fabric 302 and also so that it has poor bank-forming characteristics (i.e. the tendency to form a ridge of piled-up coating liquid) in front of blade 314. The degree of saturation will also be affected by total amount of the coating liquid deposited upon the fabric surface. In typical embodiments, the amount of semi-saturation coating liquid deposited per coating set will range from about 0.1 oz. of coating liquid/square yard of fabric to about 3 oz. of coating liquid/square yard of fabric. Spreading blade 314 utilized for spreading semi-saturation coating liquid can comprise, for example, a steel blade or a Myer rod spreader commonly utilized in the fabric coating arts, or, alternatively, can comprise a flexible elastomeric spreading blade, as described in more detail below in the context of steps 2 and 3 of FIG. 4. If desired, as shown by arrow 402 of FIG. 4, an additional semi-saturation coating layer may be applied to the fabric by repeating optional step 1. In some preferred embodiments, two semi-saturation

coating steps are performed on the fabric so that a semi-saturation coat is applied to each side of the base fabric.

Step 2 illustrated in FIG. 4 involves the formation of a conformal coating on a surface of the woven fabric. The coating liquid used in step 2 for forming the conformal coating layer includes the base acrylic latex emulsion, and further includes, in preferred embodiments, both carbon black and an additional abrasive particulate filler, for example, silicon carbide, each preferably present in an amount of between about 5 % wt. and about 40 % wt. in the coating liquid for a total abrasive particulate filler concentration of between about 10% wt. and about 40% wt. in the coating liquid. Additionally, the conformal coating liquid may, if required, also contain a sufficient amount of a viscosity modifier, for example fumed silica, in order to provide the conformal coating liquid with a paste-like viscosity sufficient to prevent substantial penetration or wicking of the coating liquid into the fiber structure upon coating.

Referring to Fig. 5, the conformal coating liquid in step 2 is applied to the surface of fabric 302 in a similar fashion as described above, and at a coating density of preferably between about 0.1 and about 3 oz/square yard of fabric also as described above. For embodiments where it is desired that the conformal coating form a breathable barrier material permeable to water vapor, or other gases, but essentially impermeable to liquid water, or other liquids, as described above, the coating should be formed of a polymer material able to form such a barrier material when in the form of a conformal coating layer, for example polyurethanes and acrylic latex polymers, and is preferably applied to the surface of the fabric at a coating density of less than about 1 oz/square yard and more preferably less than about 0.25 oz/square yard.

Unlike the semi-saturation coating liquid described above, however, the coating liquid used for conformal coating in step 2, because of its paste-like viscosity, will have less of a tendency to wick into the fabric and will tend to pile up at spreading blade 314 forming a bank of the coating liquid, as illustrated by coating liquid bank 316. In addition, when forming the conformal coating, the inventors have discovered that the uniformity of the thickness of the coating and the conformity of the contour of the coating to the topology of the fabric surface can be substantially improved, in many instances, by spreading the coating liquid with a spreading blade 314 formed of a flexible elastomeric material, for example rubber, that is maintained in essentially direct contact with the coating liquid covering the

fabric surface during the spreading step. "Direct contact" as used in the present content refers to the blade being separated from the surface of the fabric by only the coating liquid and any previously deposited polymeric coating layers on the fabric surface and not by any screens or other such layers interposed between the fabric and the blade. The inventors have found that such a spreading blade enables the formation of relatively thin uniform conformal coating layers that are essentially continuous over the surface of the fabric and that do not have regions that are scraped off of the fabric at the high points of the warp yarns, as shown above in Fig. 2, as typically occurs when using a steel bladed spreader or a Myer rod spreader as taught by the prior art. As shown by arrow 404 in Fig. 4, step 2 may be repeated to provide additional conformal coating layers on the fabric if desired.

In optional step 3 shown in Fig. 4, an additional coating layer(s) may be applied to the coated fabric on top of the conformal coating layer(s) produced from step 2 in order to provide an abrasive-free top-coating layer to the coated fabric. Such a top-coating is useful for providing a clear or colored layer to the fabric that has a smoother hand feel and, in some embodiments, such a top-coat layer(s) can also improve the washability and/or dyability of the coated fabric. For embodiments involving coated fabrics formed into gloves, this top-coating layer can be utilized to improve the grip characteristics of the coating and to improve the tactility of the gloves made from the fabric. For such embodiments, the material used for forming the top-coating layer(s) is preferably a material with a modulus of elasticity no greater than that of the material forming the conformal layer(s) applied as described above in step 2 and having a high coefficient of friction. Step 3 can be performed in an essentially identical fashion as step 2 described above except that the coating liquid utilized in step 3 preferably does not contain any abrasive particulate fillers. In addition, because the coating layer(s) are applied on top of the conformal coating layers applied in step 2, the viscosity of the coating liquid used in step 3 need not be as high as for the coating liquid in step 2 to prevent wicking into the fabric, since wicking will inherently be prevented by the presence of the coating layer(s) applied in step 2. Accordingly, the coating liquid used in step 3 can have a lower viscosity similar to that of the coating liquids used above for optional semi-saturation coating step 1. As shown by arrow 406 in Fig. 4, optional step 3 may be repeated to provide additional top-coat layers if desired.

In addition to the additives discussed above, for embodiments where a somewhat stiffer and/or more durable coating layer is desired, a small amount of a cross-linking agent

can be added to the coating liquids in any or all of the above described steps in order to increase the cross linking of the coating layer(s), for example to improve hydrolysis and/or abrasion/puncture resistance of the coating. In such embodiments, a variety of cross linking agents may be utilized depending upon the particular coating materials used. For example, when utilizing an acrylic latex emulsion based coating liquids, melamine, preferably in an amount of up to about 3 weight percent based on the total weight of the coating liquid, can be utilized to increase the degree of cross linking of the acrylic polymeric coatings.

The coated fabrics produced according to the invention, as discussed above, can be used for a wide variety of applications requiring protection against penetration of sharp objects while, at the same time, requiring drapability, flexibility, and breathability of the material. Typically, when formed into such articles of apparel for fabrics which are coated on only a single surface, it is desired to orient the coated surface so that it will be the surface that is directly exposed to the penetration or abrasion threat (i.e., an external surface of the garment or article of apparel). In many instances, it is desirable to stack the coated fabrics into multiple layers. It has been observed that, in many cases, the puncture/cut resistance of a stacked structure of more than a single layer of coated fabric produced according to the invention is increased over that of a single layer of the coated fabric by a factor that exceeds the number of stacked layers.

The function and advantage of these and other embodiments of the present invention will be more fully understood from the examples below. The following examples are intended to illustrate the operation of the present invention, but not to exemplify the full scope of the invention.

Example 1

A conformally coated protective fabric was formed according to the method outlined in Fig. 4. The base fabric utilized for coating was a 100% Kevlar® high-cover woven fabric having a weave construction of 110 x 67 (warp x fill) yarns per inch of fabric of 200 x 400 denier (warp x fill) yarn construction, wherein the yarns were comprised of spun 1.5" staple Kevlar® filaments. The warp cover factor of the fabric was about 130% to about 140% and the fill cover factor was about 85%.

One side of the base fabric was coated with two high-abrasive conformal coating layers, as described above in step 2 of Fig. 4, followed, on the same side, by two no-abrasive top-coating layers as described in optional step 3 of Fig. 4. BF Goodrich ® Sancure 861 acrylic emulsion, which forms an acrylic latex polymer having a modulus of elasticity of about 650 psi, was utilized as a base acrylic latex emulsion.

For each of the high-abrasive conformal coating layers, the coating liquid comprised: about 77.7% wt. Sancure 861; about 5.8% wt. carbon black (Monarch 280, Cabot, Tuskaloosa, AL, average particle size of about 45nm); about 13.6% wt. of granular silicon carbide (about 220 mesh size); and about 2.9% wt. melamine (Aerotex M3, Cytec, West Patterson, NJ). The above coating liquid was applied to the surface of the fabric in an amount of about 0.5 oz./per square yard of fabric for each layer of coating.

For each of the no-abrasive top-coating layers, a coating liquid was utilized comprising about 100% wt. of BF Goodrich ® Hycar 2679 acrylic emulsion. The coating liquid was applied, for each coat, in an amount of about 0.5 oz./square yard of fabric.

After coating, the samples were tested for stiffness using ASTM D4032 circular bending test. The test was performed both with the force applied to the coated surface (Face up) and with the force applied to the non-coated surface (Face down). The results, shown in Table 1, indicate that the maximum load measured in the circular bending test, which is proportional to stiffness, was increased over that measured for the base fiber alone by only about a factor of 1.1.

Example 2

The coated fabric prepared according to the present example was coated with two conformal high-abrasive coating layers followed by two no-abrasive top-coating layers in a similar fashion as described above in example 1, and was, in addition, subjected to two semi-saturation coating steps prior to formation of the conformal coating, as described in optional step 1 of Fig. 4 above, so that one semi-saturation coating was applied to each side of the base fabric prior to conformal coating.

The semi-saturation coating liquid utilized for each of the semi saturation coating applications comprised: about 97.6% wt. of the Hycar 2679 acrylic latex emulsion in combination with about 2.4% wt. of the Monarch 280 carbon black Each of the semi-

saturation coatings were applied to the fabric in an amount of about 0.5 oz./square yard of fabric.

For each of the high-abrasive conformal coating layers, the coating liquid comprised: about 80% wt. Hycar 2679 acrylic latex emulsion; about 6% wt. Monarch 280 carbon black; and about 14% wt. of granular silicon carbide (about 220 mesh size); for each of the high-abrasive coating layers. The above coating liquid was applied to the surface of the fabric in an amount of about 0.5 oz./per square yard of fabric for each layer of coating.

For each of the no-abrasive top coating layers, a coating liquid was utilized comprising about 100% wt. of the Hycar 2679 acrylic emulsion. The coating liquid was applied, for each coat, in an amount of about 0.5 oz./square yard of fabric.

As shown in Table 1, the resistance to circular bending load was increased over the base fiber by a factor of about 1.4 (Face up) to about 1.7. In addition to measuring fabric stiffness, via the above mentioned circular bending test, for the present example, penetration resistance of the fabric was also determined. Penetration resistance was measured using the modified needle puncture test similar to ASTM F 1342, except that the puncture death was controlled to 30/1000" through the fabric. As shown in Table 1, the resistance to puncture with a 0.05 inch diameter needle was about twice that of the base fabric and with the 0.042 inch diameter needle was about 1.14 times that of the base fabric. Also, as shown in Table 2, the cut resistance of a single layer of the coated fabric (row 2), as measured by ASTM S 1790, was increased over the base fabric by about a factor of about 2.3.

Table 2 also illustrates the effect of layering the coated fabric on cut and puncture resistance. Row three of Table 2 presents results obtained for cut and penetration resistance for a two layer stack of the coated fabric as measured by ASTM S 1790 and ASTM F 1342 test respectively. The results indicated that the cut resistance of the two layer stack was increased over that of the single coated fabric layer by about a factor of 2.14, and the puncture resistance of the two layer stack was increased over that of the single coated fabric layer by about a factor of 2.31.

Example 3

The coated fabric of example 3 was prepared substantially as described in example 2 above except utilizing coating liquids for the two semi-saturation coating applications, the

two high-abrasive conformal coating layers, and the two no-abrasive top coat layers having the following compositions.

The semi-saturation coating liquid utilized for each of the semi saturation coating applications comprised: about 98.3% wt. of the Hycar 2679 acrylic latex emulsion in combination with about 1.7% wt. of the Monarch 280 carbon black Each of the semi-saturation coatings were applied to the fabric in an amount of about 0.5 oz./square yard of fabric.

For each of the high-abrasive conformal coating layers, the coating liquid comprised: about 78.4% wt. Sancure 13077 acrylic latex emulsion, which forms an acrylic latex polymer having a modulus of elasticity of about 1710 psi; about 5.9% wt. Monarch 280 carbon black; about 13.7% wt. of granular silicon carbide (about 220 mesh size); and about 2.0% wt. melamine for each of the high-abrasive coating layers. The above coating liquid was applied to the surface of the fabric in an amount of about 0.5 oz./per square yard of fabric for each layer of coating.

For each of the no-abrasive top coating layers, a coating liquid was utilized comprising about 100% wt. of the Hycar 2679 acrylic emulsion. The coating liquid was applied, for each coat, in an amount of about 0.5 oz./square yard of fabric.

As shown in table 1, the coated fabric produced according to the present example had a stiffness, as measured by the circular bending test, of about 1.8 (Face up) to about 1.9 (Face down) times that of the base, uncoated fabric.

Table 1.

Sample	ASTM D 032 Circular Bending (lb Force)		Modified ASTM F 1432 Needle Puncture (lb Force)	
	Face Up	Face Down	0.05" Needle	0.042" Needle
Base Fabric	6.76	---	2.04	2.71
Example 1	7.21	7.54	---	---
Example 2	9.15	11.2	4.06	3.09
Example 3	11.9	12.7	---	---

Table 2.

Sample	ASTM F 1790 Cut Resistance (lb Force)	ASTM F 1432 Needle Puncture (lb Force)
Base Fabric	2.39	---
Example 2 (single layer)	5.45	14.3
Example 2 (double layer)	11.67	33.2

Example 4

A conformally coated protective fabric was formed according to the method outlined in Fig. 4. The base fabric utilized for coating was a 100% polyester woven fabric having a weave construction of 129 x 70 (warp x fill) yarns per inch of fabric of 220 x 220 denier (warp x fill) yarn construction, wherein the yarns were comprised of spun 1.5" staple polyester filaments. The warp cover factor of the fabric was about 76% and the fill cover factor was about 83%.

The coated fabric prepared according to the present example was coated, on one side, with two abrasive conformal coating layers, and was, in addition, subjected to two semi-saturation coating steps prior to formation of the conformal coating, as described in optional step 1 of Fig. 4 above, so that one semi-saturation coating was applied to each side of the base fabric prior to conformal coating.

The semi-saturation coating liquid utilized for each of the semi saturation coating applications comprised: about 97.6% wt. of the Hycar 2679 acrylic latex emulsion in combination with about 2.4% wt. of the Monarch 280 carbon black Each of the semi-saturation coatings were applied to the fabric in an amount of about 0.5 oz./square yard of fabric.

For each of the abrasive conformal coating layers, the coating liquid comprised: about 77.7% wt. Sancure 861; about 19.4% wt. carbon black (Monarch 280, Cabot, Tuskaloosa, AL, average particle size of about 45 nm); and about 2.9% wt. melamine (Aerotex M3, Cytec, West Patterson, NJ). The above coating liquid was applied to the surface of the fabric in an amount of about 0.5 oz./per square yard of fabric for each layer of coating.

Having thus described certain embodiments of the present invention, various alterations, modifications and improvements will be obvious to those of ordinary skill in the art. Such alterations, modifications and improvements are intended to be within the scope of the present invention. Accordingly, the above description is meant by way of example only and is not intended to be limiting. The present invention is limited only by the claims listed below and equivalents thereto.

What is claimed is:

1. An article comprising:

at least one layer of fabric; and

at least one coating layer including a polymeric material, said layer disposed on at least a portion of at least one surface of said fabric;

said polymeric material comprising an elastomeric material having a modulus of elasticity not exceeding about 100,000 psi;

said coating layer further including dispersed therein at least one abrasive particulate filler material; and

said coating layer being disposed on said surface such that at least a portion of said surface is conformally coated with said layer.

2. The article as recited in claim 1, wherein said fabric comprises a woven fabric.

3. The article as recited in claim 2, wherein said woven fabric comprises a plurality of fill yarns and a plurality of warp yarns and has a fill yarn cover factor of at least about 75% and a warp yarn cover factor of at least about 100%.

4. The article as recited in claim 1, wherein said polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 50,000 psi.

5. The article as recited in claim 4, wherein said polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 10,000 psi.

6. The article as recited in claim 5, wherein said polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 5,000 psi.

7. The article as recited in claim 1, wherein said coating layer has a essentially uniform thickness across the surface.

8. The article as recited in claim 1, wherein said woven fabric includes at least one performance fiber having a tensile breaking strength of at least about 10 g/denier.

9. The article as recited in claim 8, wherein said woven fabric consists essentially of performance fibers having a tensile breaking strength of at least about 10 g/denier.

10. The article as recited in claim 8, wherein said performance fiber is selected from the group consisting of: para-aramids; liquid crystal polyesters; ultra-high molecular weight polyethylenes; and poly(p-phenylene-2,6-benzobisoxazole (PBO).

11. The article as recited in claim 10, wherein said performance fiber comprises a para-aramid.

12. The article as recited in claim 1, wherein said polymeric material comprises an acrylic polymer.

13. The article as recited in claim 1, wherein said polymeric material comprises a polyurethane.

14. The article as recited in claim 1, wherein said abrasive particulate filler material comprises carbon black.

15. The article as recited in claim 1, wherein said coating layer further includes a color pigment.

16. The article as recited in claim 1, wherein said abrasive particulate filler comprises an inorganic, material.

17. The article as recited in claim 16, wherein said abrasive particulate filler comprises a ceramic material.

18. The article as recited in claim 17, wherein said ceramic material is selected from the group consisting of: silicon carbide; aluminum oxide; silicon dioxide; garnet; and combinations thereof.

19. The article as recited in claim 1, wherein said abrasive particulate filler material comprises diamond.

20. An article comprising:

at least one layer of a fabric, said fabric including at least one performance fiber having a tensile breaking strength of at least about 10 g/denier; and

at least one coating layer including a polymeric material, said layer disposed on at least a portion of at least one surface of said fabric;

said polymeric material comprising an elastomeric material having a modulus of elasticity not exceeding about 100,000 psi.

21. The article as recited in claim 20, wherein said fabric comprises a woven fabric.

22. The article as recited in claim 21, wherein said woven fabric comprises a plurality of fill yarns and a plurality of warp yarns and has a fill yarn cover factor of at least about 75% and a warp yarn cover factor of at least about 100%.

23. The article as recited in claim 20, wherein said polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 50,000 psi.

24. The article as recited in claim 23, wherein said polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 10,000 psi.

25. The article as recited in claim 24, wherein said polymeric material comprises an elastomeric material having a modulus of elasticity not exceeding about 5,000 psi.

26. The article as recited in claim 20, wherein the coating layer is disposed on the surface such that at least a portion of the surface is conformally coated with said layer.

27. The article as recited in claim 26, wherein the coating layer is disposed on the surface of the fabric such that it has a essentially uniform thickness across the surface.

28. The article as recited in claim 20, wherein said woven fabric consists essentially of performance fibers having a breaking strength of at least about 10 g/denier.

29. The article as recited in claim 20, wherein said performance fiber is selected from the group consisting of: para-aramids; liquid crystal polyesters; ultra-high molecular weight polyethylenes; and poly(p-phenylene-2,6-benzobisoxazole)(PBO).

30. The article as recited in claim 29, wherein said performance fiber comprises a para-aramid.

31. The article as recited in claim 20, wherein said polymeric material comprises an acrylic polymer.

32. The article as recited in claim 20, wherein said polymeric material comprises a polyurethane.

33. The article as recited in claim 20, wherein said coating layer further includes dispersed therein at least one abrasive particulate filler material.

34. The article as recited in claim 33, wherein said abrasive particulate filler material comprises carbon black.

35. The article as recited in claim 20, wherein said coating layer further includes dispersed therein a color pigment.

36. The article as recited in claim 33, wherein said abrasive particulate filler comprises an inorganic material.

37. The article as recited in claim 36, wherein said abrasive particulate filler material comprises a ceramic material.

38. The article as recited in claim 37, wherein said ceramic material is selected from the group consisting of: silicon carbide; aluminum oxide; silicon dioxide; garnet; and combinations thereof.

39. The article as recited in claim 33, wherein said abrasive particulate filler material comprises diamond.

40. A method comprising the steps of:

a. dispersing at least one abrasive particulate filler in a liquid that is able to form a solid film on a surface, which film including a polymeric material, where said polymeric material has a modulus of elasticity not exceeding about 100,000 psi.;

b. applying the liquid onto a surface of a fabric;

c. spreading the liquid across at least a portion of the fabric surface to form a liquid layer on the fabric surface, said layer substantially conforming to a surface topology of the fabric surface; and

d. allowing the liquid layer to solidify to form a conformal coating layer on the fabric surface.

41. The method as recited in claim 40, wherein said polymeric material has, when in a substantially pure solid form, a modulus of elasticity not exceeding about 50,000 psi.

42. The method as recited in claim 41, wherein said polymeric material has, when in a substantially pure solid form, a modulus of elasticity not exceeding about 10,000 psi.

43. The method as recited in claim 42, wherein said polymeric material has, when in a substantially pure solid form, a modulus of elasticity not exceeding about 5,000 psi.

44. The method as recited in claim 40, wherein said abrasive particulate filler is selected from the group consisting of carbon black; ceramic materials; diamond; and combinations thereof.

45. The method as recited in claim 40, wherein in step (a) at least one color pigment is dispersed into said liquid that is able to form a solid film.

46. The method as recited in claim 40, wherein said polymeric material comprises an acrylic polymer.

47. The method as recited in claim 40, wherein said polymeric material comprises a polyurethane.

48. The method as recited in claim 40, wherein said fabric includes at least one performance fiber having a tensile breaking strength of at least about 10 g/denier.

49. The method as recited in claim 40, further comprising repeating steps (b)-(d) at least one time to form at least two conformal coating layers on the fabric surface.

50. The method as recited in claim 40, further comprising after step (d), the steps of:

e. applying a second liquid that is able to form a solid film including a polymeric material onto the coated fabric surface, where said liquid is essentially free of abrasive particulate fillers;

f. spreading the second liquid across at least a portion of the fabric surface to form an essentially abrasive-free liquid layer on the fabric surface; and

g. allowing the essentially abrasive-free liquid layer to solidify to form a coating layer on the fabric surface.

51. The method as recited in claim 40, further comprising before step (a) the steps of:

i. applying a polymer-containing or polymer-forming liquid onto at least one surface of the fabric;

ii. allowing said polymer-containing or polymer-forming liquid to wick into and penetrate essentially entirely through a cross-section of the fabric; and

iii. allowing the polymer-containing or polymer-forming liquid to solidify.

52. The method as recited in claim 51, wherein the polymer applied in step (i), when in substantially pure solid form, has a modulus of elasticity not exceeding about 100,000 psi.

53. The method as recited in claim 52, wherein the polymer applied in step (i), when in substantially pure solid form, has a modulus of elasticity not exceeding about 50,000 psi.

54. The method as recited in claim 53, wherein the polymer applied in step (i), when in substantially pure solid form, has a modulus of elasticity not exceeding about 10,000 psi.

55. The method as recited in claim 54, wherein the polymer applied in step (i), when in substantially pure solid form, has a modulus of elasticity not exceeding about 5,000 psi.

56. The method as recited in claim 51, wherein the liquid applied in step (i) has a viscosity that is substantially less than the viscosity of the liquid applied in step (b).

57. The method as recited in claim 40, wherein in step (c) the liquid is spread utilizing a spreading blade formed of a flexible elastomeric material.

58. The method as recited in claim 50, wherein in step (f) the liquid is spread utilizing a spreading blade formed of a flexible elastomeric material.

59. The method as recited in claim 40, wherein in step (a) an additive is added to the liquid, which additive is able to increase a degree of cross-linking of the polymeric material.

60. The method as recited in claim 60, wherein said additive comprises melamine.

61. A method comprising the steps of:

a. supplying a liquid that is able to form a solid film on a surface, the film including a polymeric material, where said polymeric material has a modulus of elasticity not exceeding about 100,000 psi.;

b. applying the liquid onto a surface of a fabric that includes at least one performance fiber having a tensile breaking strength of a least about 10g/denier;

c. spreading the liquid across at least a portion of the fabric surface to form a liquid layer on the fabric surface; and

d. allowing the liquid layer to solidify to form a coating layer on the fabric surface.

62. The method as recited in claim 61, wherein said polymeric material has, when in a substantially pure solid form, a modulus of elasticity not exceeding about 50,000 psi.

63. The method as recited in claim 62, wherein said polymeric material has, when in a substantially pure solid form, a modulus of elasticity not exceeding about 10,000 psi.

64. The method as recited in claim 63, wherein said polymeric material has, when in a substantially pure solid form, a modulus of elasticity not exceeding about 5,000 psi.

65. The method as recited in claim 61, further comprising after step (a) and before step (b) the step comprising:

dispersing at least one abrasive particulate filler in said liquid.

66. The method as recited in claim 61, wherein in step (c) said liquid is spread so that said liquid layer substantially conforms to a surface topology of the fabric surface.

67. The method as recited in claim 66, wherein in step (d) said liquid layer solidifies to form a conformal coating layer on the fabric surface.

68. The method as recited in claim 61, wherein in step (c) the liquid is spread utilizing a spreading blade formed of a flexible, elastomeric material.

69. A method comprising the steps of:

a. applying a film-forming liquid to a fabric surface;

b. spreading the liquid across at least a portion of said surface by utilizing a spreading blade formed of a flexible elastomeric material, where, during the spreading step, the blade is maintained in essentially direct contact with the liquid on said fabric surface.

70. An article comprising:

at least one layer of woven fabric; and

at least one coating layer including a polymeric material, said layer disposed on at least a portion of at least one surface of said fabric;

said polymeric material comprising an elastomeric material having a bulk modulus not exceeding about 100,000 psi;

said coating layer further including dispersed therein at least one abrasive particulate filler material.

71. An article comprising:

at least one layer of woven fabric; and

at least one coating layer including a polymeric material, said layer disposed on at least a portion of at least one surface of said fabric;

said coating layer further including dispersed therein at least one abrasive particulate filler material; and

said coating layer being disposed on said surface such that at least a portion of said surface is conformally coated with said layer.

72. An article comprising:

at least one layer of fabric including therein at least one performance having a tensile breaking strength of at least about 10 g/denier; and

a at least one coating layer disposed on at least a portion of at least one surface of the fabric and comprising a barrier material that is permeable to a gas but essentially impermeable to liquid water.

73. The article as recited in claim 72, wherein said barrier material is permeable to air.

74. The article as recited in claim 73, wherein said barrier material is permeable to water vapor.

75. The article as recited in claim 72, wherein said fabric comprises a woven fabric.

76. The article as recited in claim 75, wherein said woven fabric comprises a plurality of fill yarns and a plurality of warp yarns and has a fill yarn cover factor of at least about 75% and a warp yarn cover factor of at least about 100%.

77. The article as recited in claim 72, wherein said fabric consists essentially of performance fibers having a tensile breaking strength of at least about 10 g/denier.

78. The article as recited in claim 72, wherein said performance fiber is a material selected from the group consisting of: para-aramids; liquid crystal polyesters; ultra-high molecular weight polyethylenes; and poly(p-phenylene-2,6-benzobisoxazole) (PBO).

79. The article as recited in claim 72, wherein said performance fiber is a para-aramid.

80. The article as recited in claim 72, wherein said barrier material comprises an elastomeric material having a modulus of elasticity not exceeding about 100,000 psi.

81. The article as recited in claim 80, wherein said elastomeric material comprises a polyurethane.

82. The article as recited in claim 80, wherein said elastomeric material comprises an acrylic polymer.

83. The article as recited in claim 72, wherein said at least one coating layer is disposed on the surface at a thickness corresponding a specific weight of the coating layer of no greater than about 1 ounce per square yard.

84. The article as recited in claim 83, wherein said at least one coating layer is disposed on the surface at a thickness corresponding a specific weight of the coating layer of no greater than about 0.25 ounce per square yard.

85. The article as recited in claim 83, wherein said at least one coating layer has an essentially uniform thickness across the portion of the surface on which it is disposed.

86. The article as recited in claim 72, wherein said at least one coating layer further includes dispersed therein at least one abrasive particulate filler material.

87. The article as recited in claim 72, wherein said at least one coating layer is disposed on the portion of the surface such that portion is conformally coated with the coating layer.

88. A method comprising the step of:

combining at least one layer of fabric including therein at least one performance fiber having a tensile breaking strength of at least about 10 g/denier with at least one coating layer comprising a barrier material that is permeable to a gas but essentially impermeable to liquid water, so that the coating layer is disposed on at least a portion of at least one surface of the fabric.

89. An article of apparel fabricated from the articles as recited in claims 1, 20, 70, 71, or 72.

90. The article of apparel as recited in claim 89, wherein the article of apparel is selected from the group consisting of gloves; aprons; chaps; pants; boots; gators; and gauntlets.

91. A multi-layer stack comprising a least two layers of an article as recited in claims 1, 20, 70, 71, or 72.

92. An article of apparel fabricated from a coated fabric produced according to a method as recited in any of claims 40, 61, 69, or 88.

93. The article of apparel as recited in claim 92, wherein the article of apparel is selected from the group consisting of gloves; aprons; chaps; pants; boots; gators; and gauntlets.

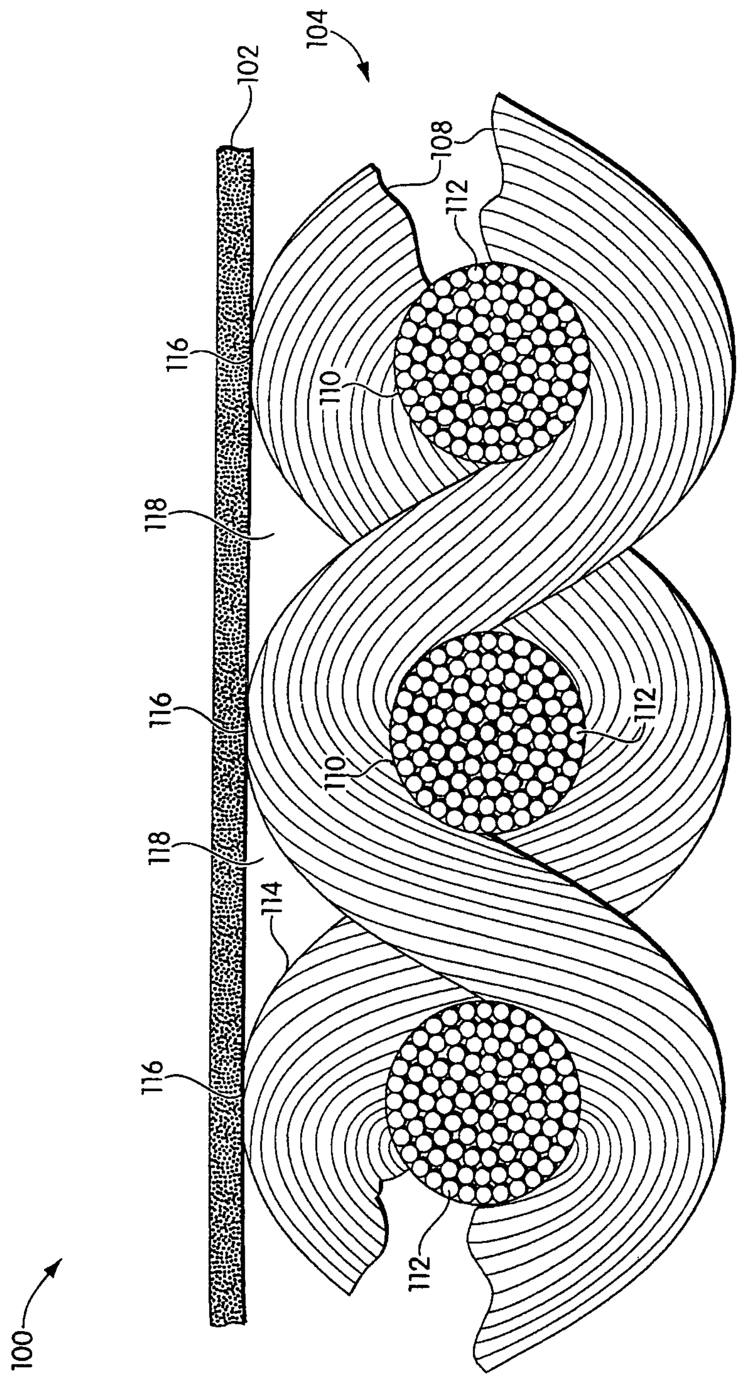

Fig. 1

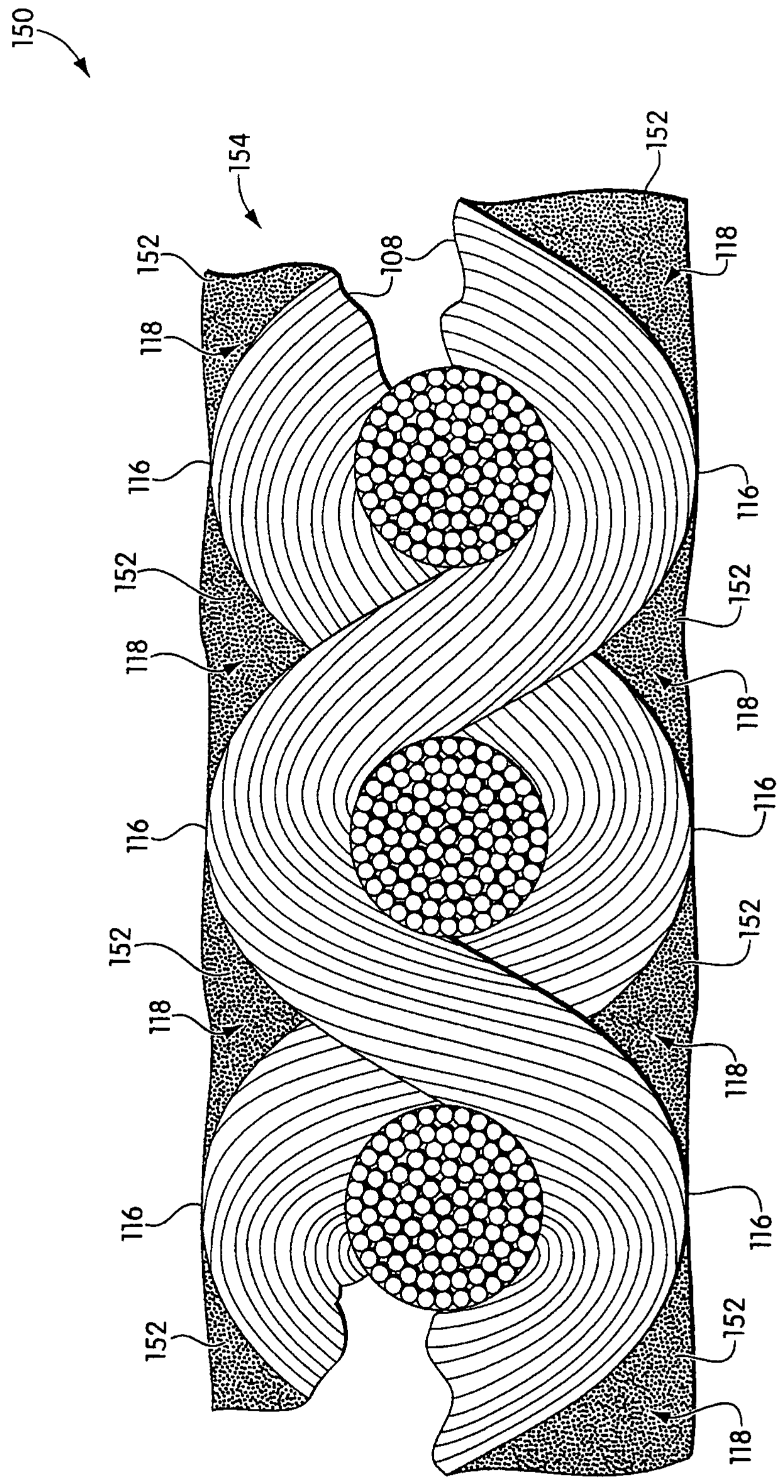
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Fig. 2

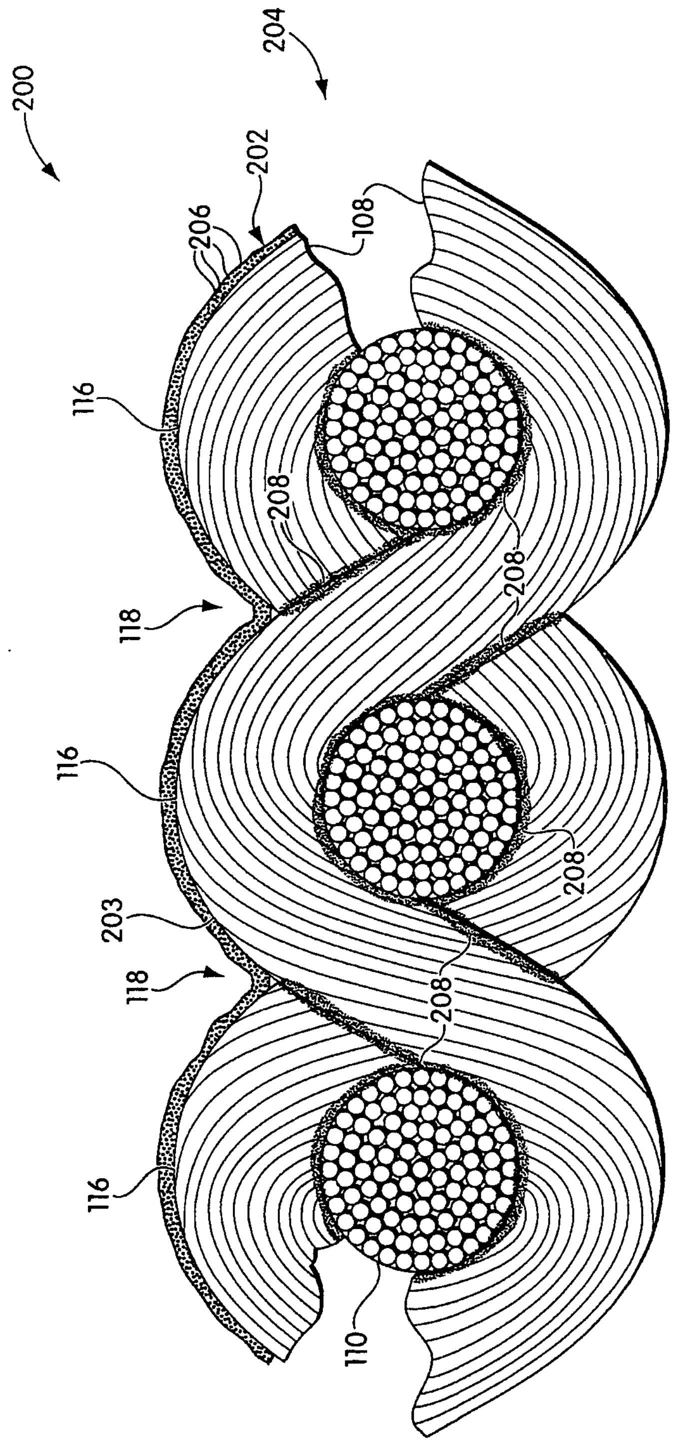

Fig. 3

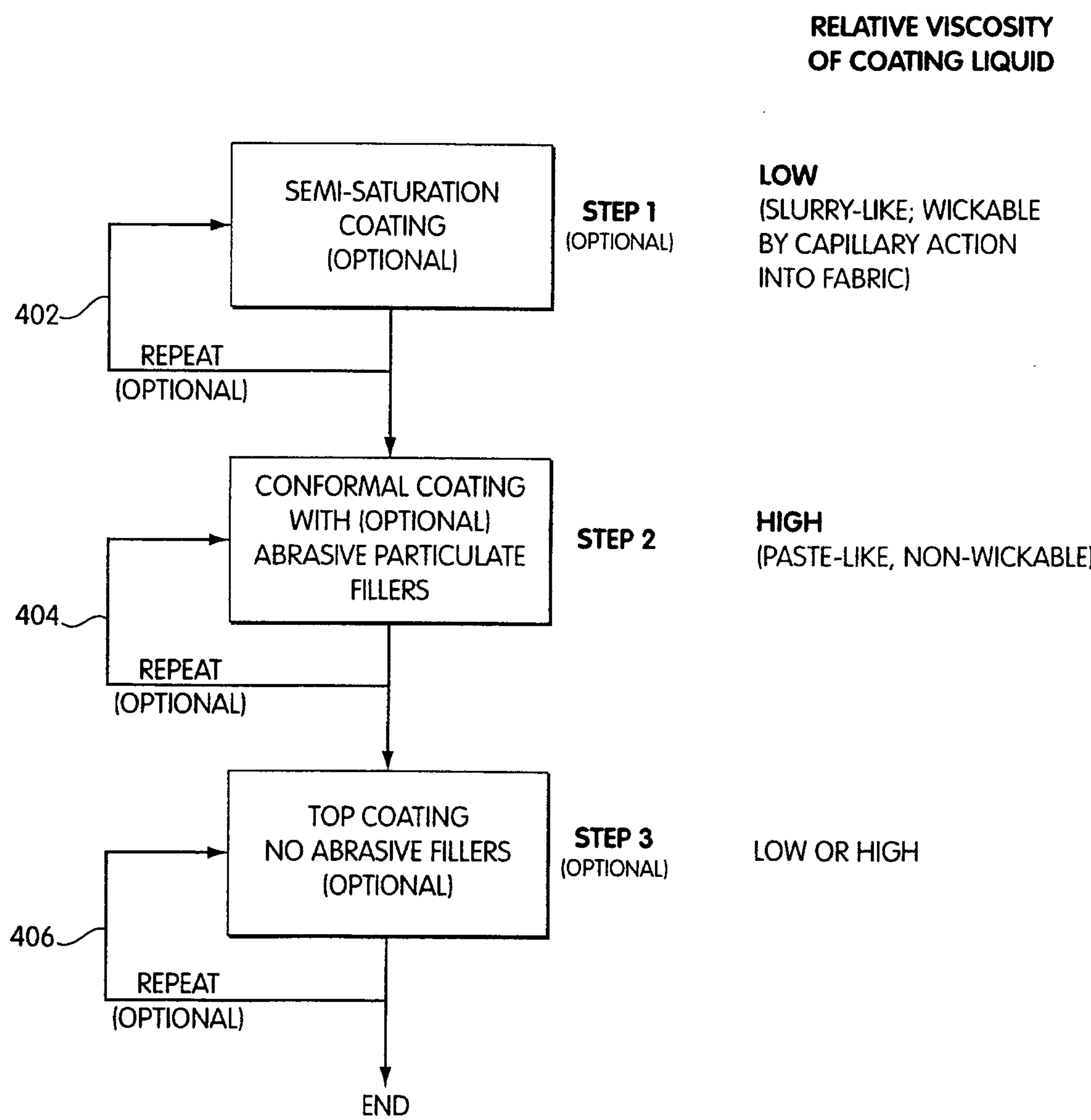
RELATIVE VISCOSITY
OF COATING LIQUID
SEMI-SATURATION
COATING
(OPTIONAL)
STEP 1
(OPTIONAL)
LOW
(SLURRY-LIKE; WICKABLE
BY CAPILLARY ACTION
INTO FABRIC)
402
REPEAT
(OPTIONAL)
CONFORMAL COATING
WITH (OPTIONAL)
ABRASIVE PARTICULATE
FILLERS
STEP 2
HIGH
(PASTE-LIKE, NON-WICKABLE)
404
REPEAT
(OPTIONAL)
TOP COATING
NO ABRASIVE FILLERS
(OPTIONAL)
STEP 3
(OPTIONAL)
LOW OR HIGH
406
REPEAT
(OPTIONAL)
END

Fig. 4

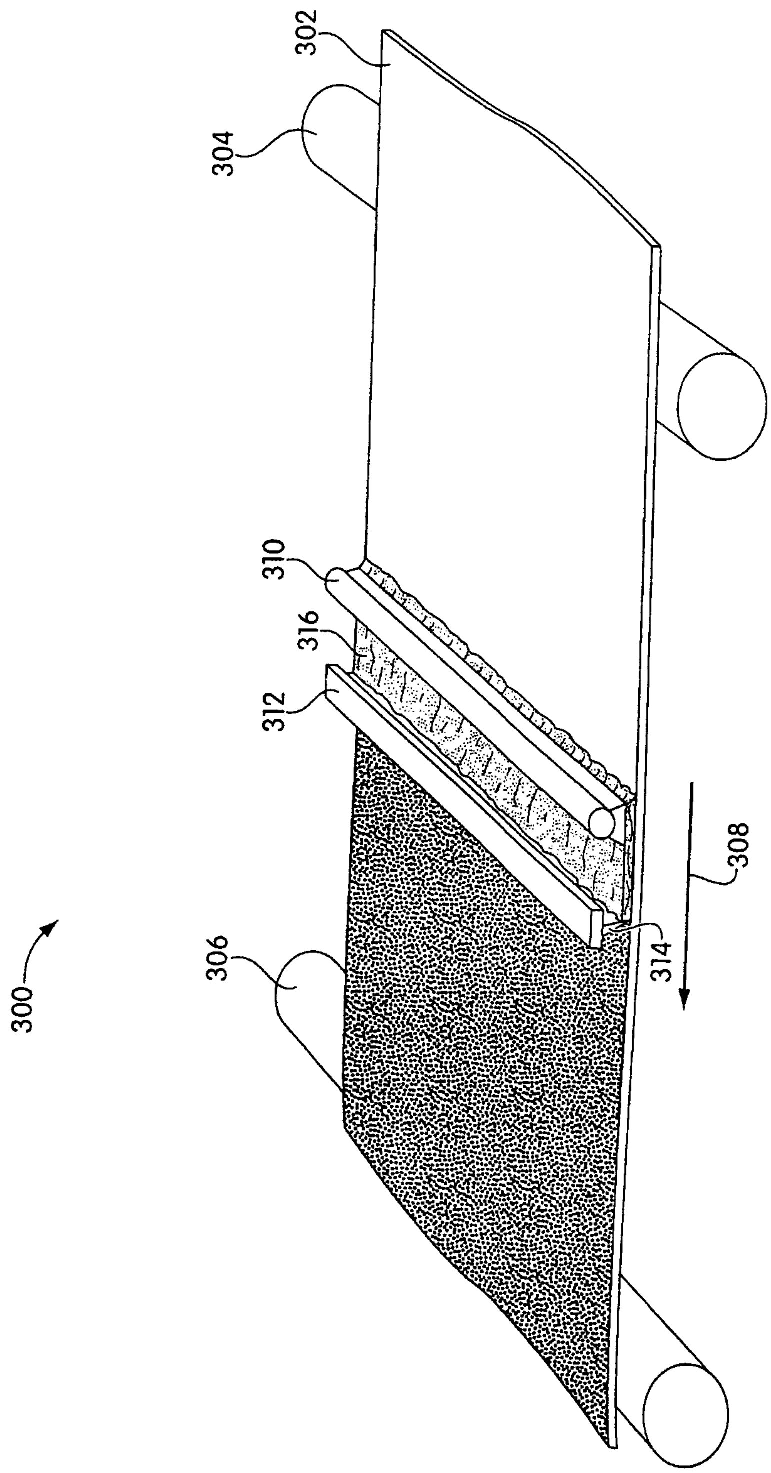

Fig. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/28796

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 D06N7/00 D06N3/04 D06N3/14 A41D19/015 A41D31/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 D06N A41D F41H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
9 X	WO 99 17626 A (HOECHST CELANESE CORP) 15 April 1999 (1999-04-15)	1,2, 4-11, 13-21, 23-30, 32-45, 47,48, 61-67, 70,71, 89,90, 92,93
Y	the whole document ---	3,22,91

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 July 2001	20.07.01

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pamies Olle, S

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/28796

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

	Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
11	X	US 5 589 254 A (DISCHLER LOUIS) 31 December 1996 (1996-12-31)	20,21, 23-25, 28-30, 61-64, 89-93
	A	column 3, line 25 -column 4, line 16	1-6, 8-11,40, 70,71

8	P,X	US 6 044 493 A (POST DAVID G) 4 April 2000 (2000-04-04)	20,21, 23-25, 29,30, 32, 61-64, 89,90, 92,93
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11	X	DATABASE WPI Section Ch, Week 199307 Derwent Publications Ltd., London, GB; Class A28, AN 1993-055402 XP002171359 & JP 05 005276 A (TORAY IND INC), 14 January 1993 (1993-01-14)	72-75, 78,79, 81, 88-90, 92,93
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12	Y	US 5 565 264 A (HOWLAND CHARLES A) 15 October 1996 (1996-10-15) cited in the application claims	3,22,76, 91

11	Y	US 5 308 689 A (SHINKAI TSUNEHISA ET AL) 3 May 1994 (1994-05-03) column 3, line 35 - line 54; claims; figures column 4, line 26 - line 32	72-75, 77-79, 81, 88-90, 92,93

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/28796

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 634 215 A (DEBAENE DAVID N) 3 June 1997 (1997-06-03) column 3, line 14 - line 61; claims; figures ---	72-75, 77-79, 81, 88-90, 92,93
A	DE 198 02 242 A (AKZO NOBEL NV) 5 August 1999 (1999-08-05) the whole document ---	1,2, 8-11,13, 16-18, 20,21, 28-30, 32,33, 36-38, 40,44, 47-50, 61,65, 70,71, 89-93
A	DE 196 24 245 C (SAECHSISCHES TEXTILFORSCH INST) 23 October 1997 (1997-10-23) the whole document ---	72-93
A	US 4 518 650 A (GROT WALTHER G ET AL) 21 May 1985 (1985-05-21) column 4, line 15 - line 39; claims 1,5,7,11; example 2 column 12, line 35 - line 64 -----	72-93

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 00/28796

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [X] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

1-68, 70, 71 (partly), 72-88, 89-93 (partly).

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[X] No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-68, 70, 71 (partly), 89-93 (partly)

   Article comprising a fabric coated with an elastomer, method for making it and apparel made from it.

2. Claims: 69, 92-93 (partly)

   Method of coating a fabric by spreading a film-forming liquid composition with a spreading blade.

3. Claims: 71 (partly) and 89-93 (partly)

   Article comprising a fabric coated with a polymer, other than elastomer, containing an abrasive particulate filler dispersed in it, method for making it and apparel made from it.

4. Claims: 72-88 and 89-93 (partly)

   Article comprising a fabric, which includes at least one performance fiber having a tensile breaking strength of at least 10g/denier, coated with a barrier material, which is permeable to gas but impermeable to liquid water, method for making it and apparel made from it.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/28796

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
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